POSSIBLE MECHANISMS OF THE CHICXULUB DISTAL EJECTA EMPLACEMENT. N. Artemieva[1,2] and J. Morgan[3], [1]Institute for Dynamics of Geospheres 119334 Moscow, [2]Planetary Science Institute 85719 Tucson artemeva@psi.edu, [3]Imperial College London, UK, j.morgan@imperial.ac.uk

Introduction: The K-P boundary is widely recognized as a global ejecta layer formed by a large meteorite impact 65 million years ago. The discovery of an iridium anomaly [1] and shocked quartz grains [2] within the K-P boundary layer provided the strongest confirmation of the impact hypothesis. The Chicxulub crater, a 'smoking gun' was discovered following a decade of studies of these worldwide ejecta deposits [3]. Although we now have good constraints on the size of this impact [3-5] and geochemistry of the target rocks [6-8], the mechanism for transporting the ejecta world-wide is still a subject of much debate.

Numerical methods and initial conditions. We model the impact, ejecta origin, and ejecta re-entry using 3D hydrocode SOVA [9] complemented by the ANEOS equation of state for geological materials [10].

The modeled Chicxulub target consists of a 3-km-thick sedimentary layer, a 30-km-thick crystalline basement, and mantle. We use granite and dunite EOSs to describe the basement and the mantle, respectively. The sedimentary layer is modeled as 1) non-porous limestone (calcite EOS) and 2) porous water-saturated limestone (mixed calcite/water EOS similar to [11]). We also vary a projectile size, an impact angle and an impact velocity, keeping the transient cavity size constant and equal to 90-100 km.

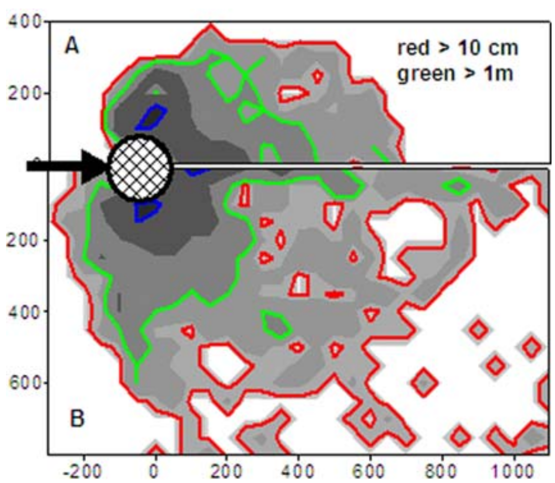

Fig. 1 Distribution of the Chicxulub proximal basement ejecta after a 45° impact. **A:** dry non-porous sedimens; **B:** water-saturated sediments. The crater is shown by a circle, impact direction – by an arrow.

Ejection of basement material. While a lot of high-velocity (up to escape) ejecta leave the crater, the basement material (initially at a depth > 3 km) is ejected with velocities below 3 km/s for all tested impact scenarios. The modeled proximal ejecta deposits are formed from a molten silica-rich mixture of basement and sediments, in agreement with observations (Fig. 1). However, velocities of > 6 km/s are required to eject material around the globe ballistically, hence basement material does not reach distal locations in our modeling. This leads to the question as to how basement material (shocked quartz and zircon) is transported to the distal K-P ejecta layer (it is quite possible that the K-P spherules are derived exclusively from projectile and target sediments).

The origin of shocked minerals in the K-P layer.

Acceleration in a plume. It has been proposed that the shocked minerals are accelerated to high velocity in the expanding plume [12]. This idea was confirmed by modeling [13], albeit for the initial stage of impact only. To investigate this idea, we have examined the mass-velocity distributions for ejected particles at radii of 100, 200 and 300 km. We do not observe any substantial acceleration of basement particles. This result was expected, as 1) there is very little, if any, vapor in these ejecta; 2) turbulent mixing is not efficient on a large scale over a short time of the plume initial expansion.

Quartz and zircon within target sediments. No quartz has been observed in Cretaceous sediments in Yucatán drill cores [14-15]. However, we cannot dismiss this as a possible explanation, as we only require a quartz abundance of less than 1% to create the known shocked quartz distribution, and the sampling of the Upper Cretaceous is imperfect – the holes are sparsely distributed, old holes are only partially cored, and the uppermost Cretaceous is missing in some wells [16].

Transfer of basement material within atmospheric winds. This mechanism is well-known from catastrophic volcanic eruptions (see for example description of El Chichon eruption in 1982 in [17]), was proposed for the Chicxulub ejecta in [18-19]. and was modeled by Pope [20], assuming 10^{16}-10^{17} g of clastic material at stratospheric altitudes near the Chicxulub. Estimated amount of world-wide shocked quartz is at the minimum limit of our estimates for particles suspended in the plume. This variant looks plausible, because the age of zircon grains points to their origin from the basement [21]. Moreover, non-ballistic (and hence – with low velocity and at low altitudes) transport of quartz grains may explain the fact that PDF survive upper atmosphere heating during re-entry. If shocked quartz arrived at the same time (and with the same velocity) as the ballistic ejecta, quartz would be annealed [22]. The problem with this mechanism is that atmospheric flows tend to distribute fine-grained materials in certain directions (mainly along the equatorial zone) not world-wide.

Transfer of basement material by "skidding". Additional redistribution of re-entry ejecta by the Earth's atmosphere has been described qualitatively 20 years ago in [23] and is studied intensively with the KFIX-LPL code [24]. The principal idea is quite simple – re-entering high-velocity debris heats the atmosphere, which then expands laterally and redistributes the debris around the globe in several hours (not in several weeks as for volcanic ashes). In Figure 2, ejecta arrives in the undisturbed atmosphere at an altitude of 100 km with a velocity of 2 km/s, transferring energy from the ejecta to the atmosphere and causing shock waves. Its total mass corresponds to a 14-cm-thick layer on the surface. In upper atmosphere it moves ballistically and transfers its energy to the gas, creating shock waves. At lower altitudes atmospheric disturbances become strong enough to disperse ejecta – first uprange and later downrange.

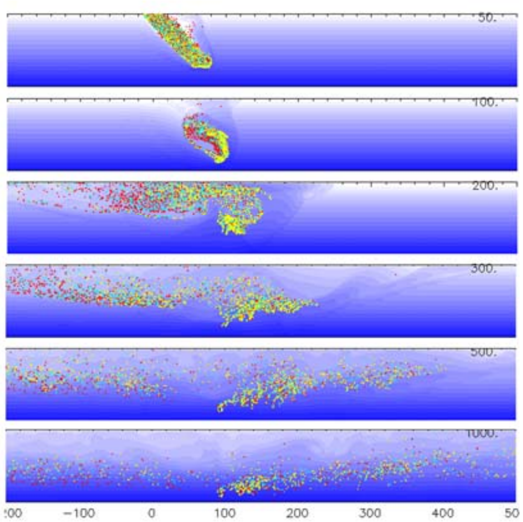

Fig. 2. Snapshots (time moments are shown in the upper right corners) of ejecta re-distribution during re-entry. Different colors represent particles of different sizes: red - 100 μm, cyan – 1 mm, yellow – 1 cm).

The effect depends obviously on the ejecta mass, velocity, particle size distribution. In Fig. 3 the resulting deposit thickness is shown. Two gray rectangles show two ideal cases – pure ballistics without substantial deceleration (B) and quick deceleration in upper atmosphere following by slow sedimentation (S). In both cases the thickness should be 14 cm at the 25-km-diameter area (as we started with 25-km-diameter ejecta "beam"). Instead, we have 2 cm of ejecta in the center and more or less constant 1-mm-thick ejecta layer at the distances up to 400 km downrange and uprange. Approximately 1/3 of ejecta are deposited even further - outside the computational area. The real re-entry is much more complicated.

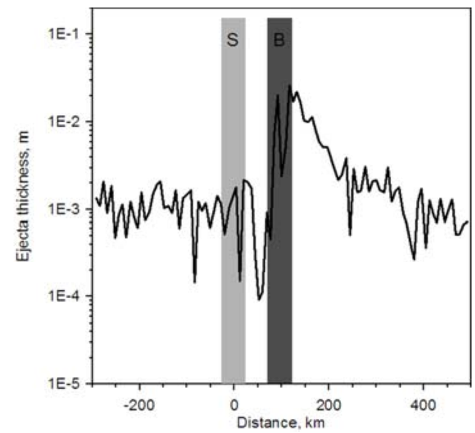

Fig. 3 Thickness of ejecta (from fig.2) on the ground**. S** and **B** represent non-dispersed ejecta.

Conclusions. Impact glasses from proximal sites (~900-1200 km from the Chicxulub) originated from the crystalline basement in mixture with sedimentary melt/vapor. Distal ejecta from the Chicxulub representing mainly vaporized/molten projectile and sediments were emplaced ballistically. Shocked quartz from the crystalline basement was emplaced non-ballistically (by skidding effect and/or by atmospheric flows). We also can not exclude their origin from quartz inclusions in upper (< 500 m) Cretaceous sediments.

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